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Title: Trapping of Implanted He at Cu/Nb Interfaces Measured by Neutron Reflectometry

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Trapping of Implanted He at Cu/Nb Interfaces Measured by Neutron Reflectometry

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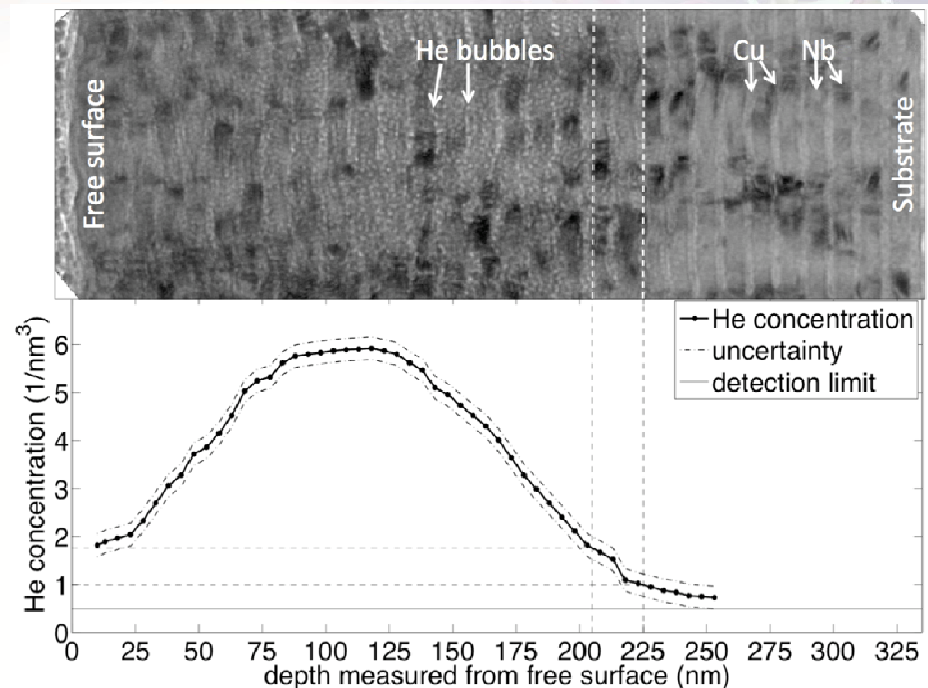
LANSCE-LC

Motivation

In single crystalline metals, He is insoluble and precipitates into bubbles

In contrast, Cu-Nb multilayers show no evidence of bubble formation below a critical concentration

Questions

- How are the He atoms stored at the interface below the critical concentration?
- What is the C_{He} distribution?

[1] M. J. Demkowicz et al, Appl. Phys. Lett. 97 (2010) 161903

In Cu-Nb multilayers, the critical interface He concentration to resolve bubbles under the TEM is 8.5±2.5 atoms/nm^2 [1] (Multilayers implanted with 35 keV He^3 with 10^{17}/cm^2).

Why Neutron Reflectometry (NR)?

- **Advantages of NR:**
  - Element sensitive
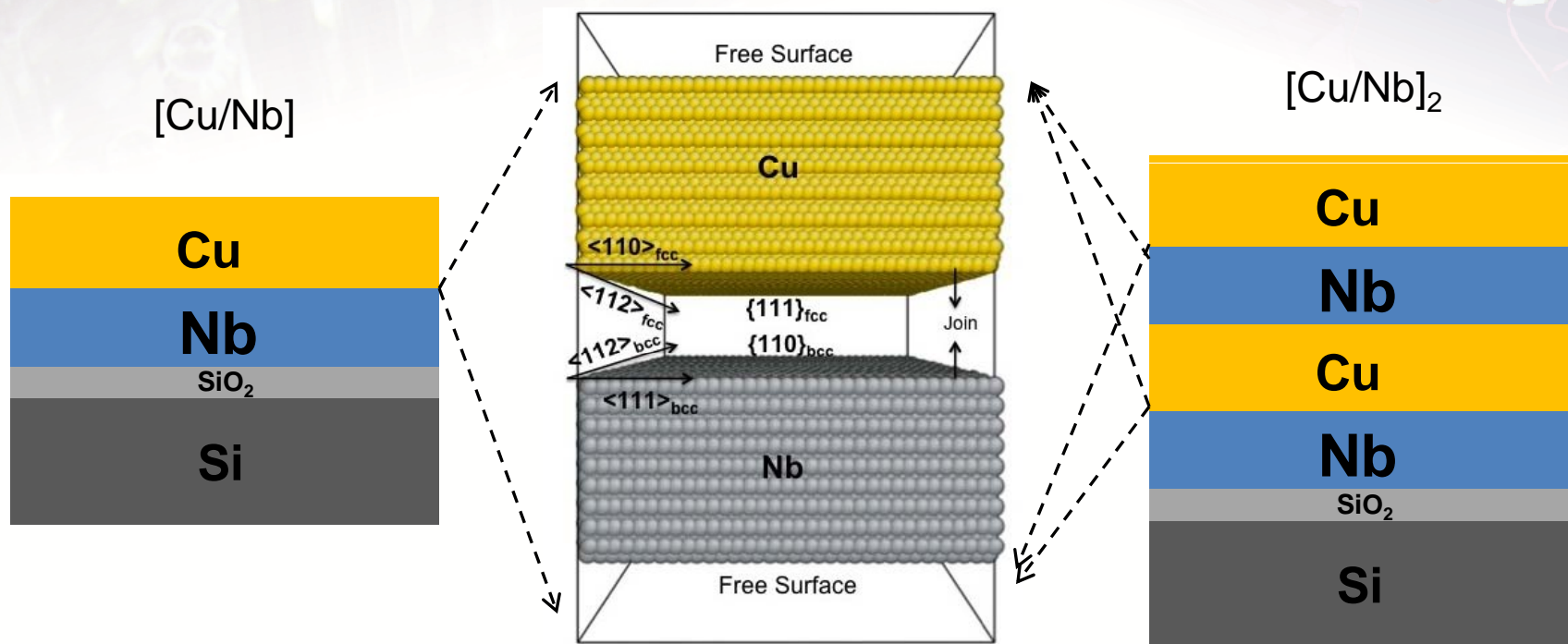 - Angstrom level depth resolution
  - Nondestructive in nature
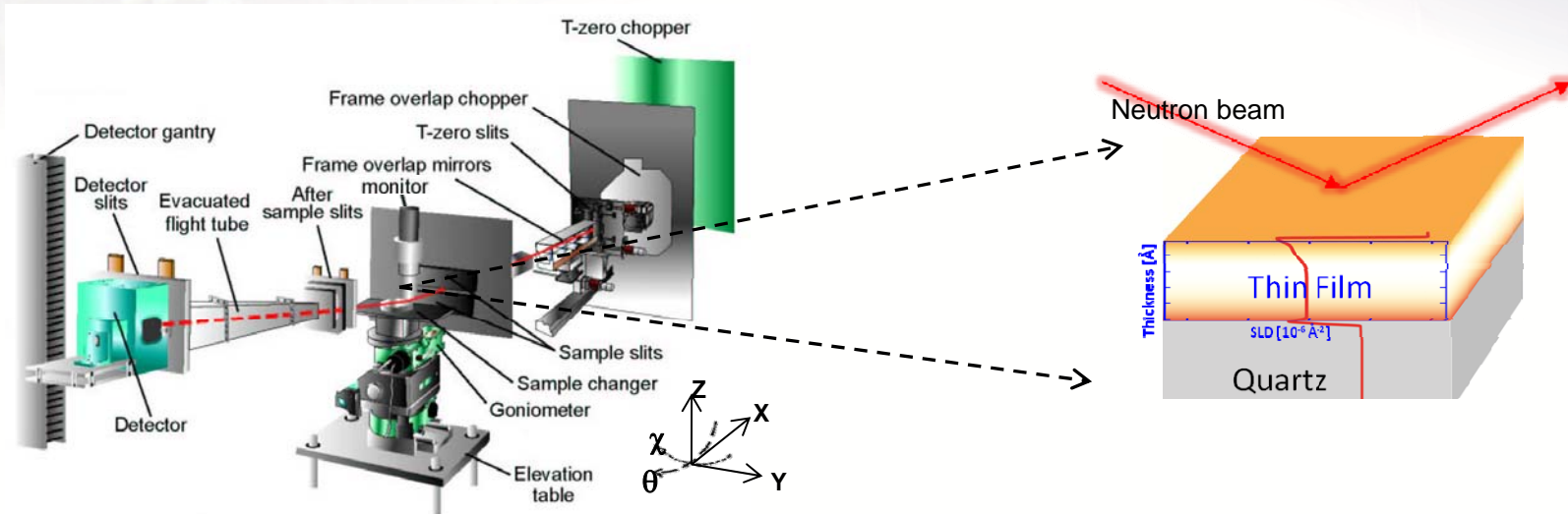
TEM: Cannot resolve He clusters smaller than 2 nm in diameter
Elastic Recoil Detection (ERD): NOT enough depth resolution
Nuclear Reaction Analysis (NRA): NOT enough depth resolution

Cu/Nb bi-layers: Magnetron Sputtering
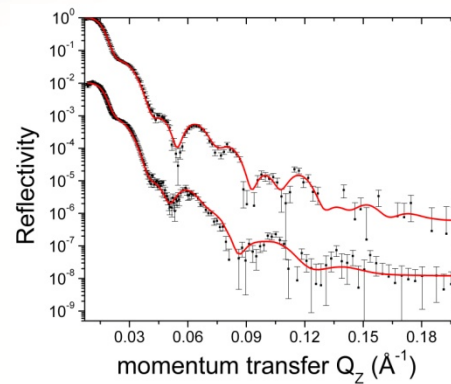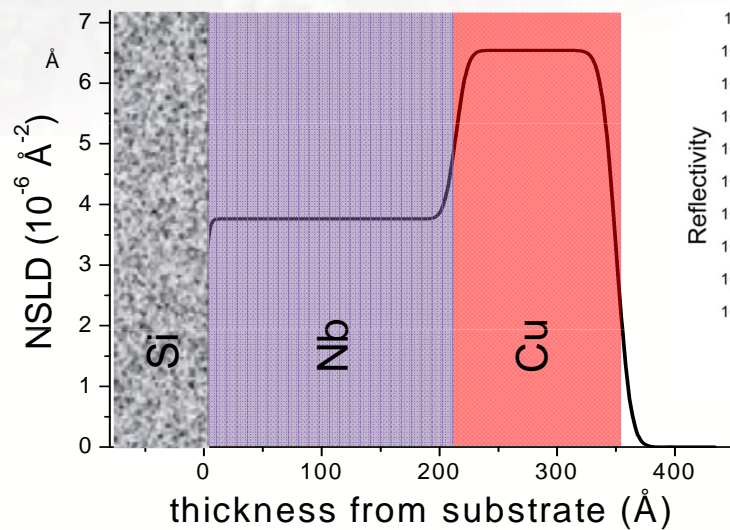## He Implantation: 20 KeV, 10^{17} ions/cm^2, < 2 μA/cm2

[Cu/Nb]

[Cu/Nb]$_2$

Construction of the Cu-Nb heterointerface.

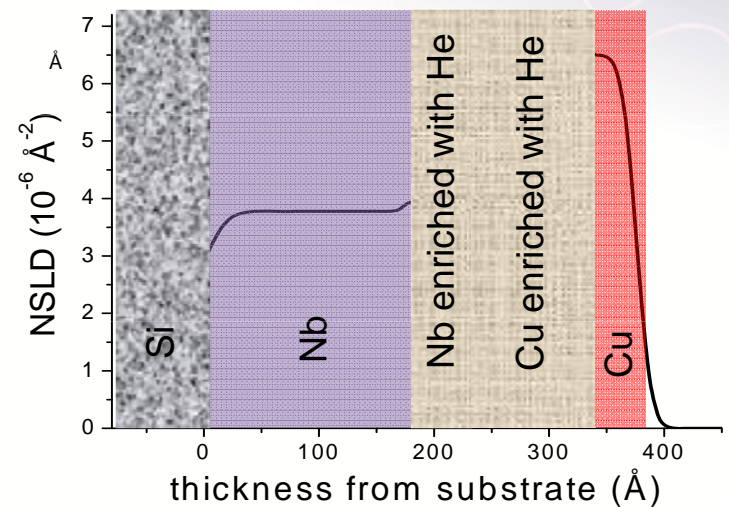## Kurdjumov-Sachs (KS) orientation relationship

As-prepared

He-implanted

- He trapped at Cu/Nb interface
- Cu is preferred

	Layer	Thickness (Å)	SLD (10^{-6} Å^{-2})	Roughness (Å)	He (at. %)
As-prepared	Cu	136	6.54	14	
	Nb	211	3.76	11	
After Implantation	Cu	42	6.5	14.5	
	Cu + He	108	7.06	4	18
	Nb + He	53	3.95	15	12
	Nb	173	3.78	6	

- Significant broader interface
  -- 160 Å vs. 11Å
- Cu layer swelled 10%
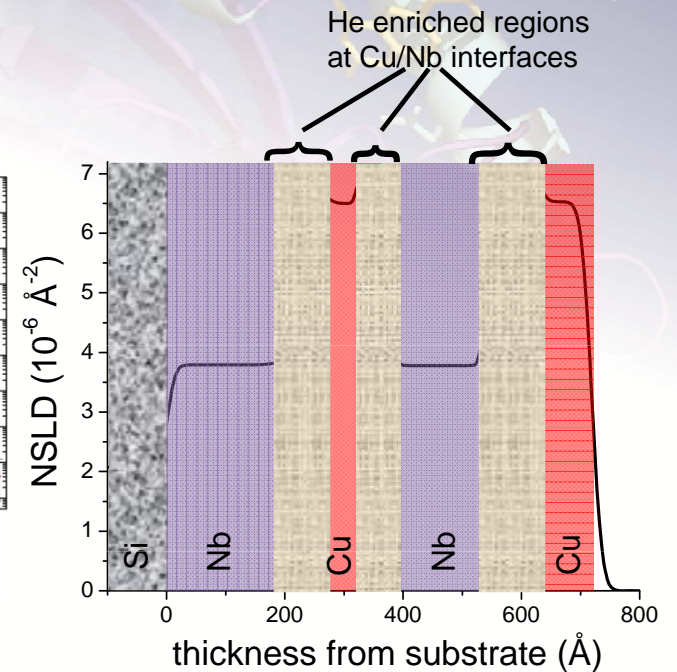- Nb layer swelled 7%
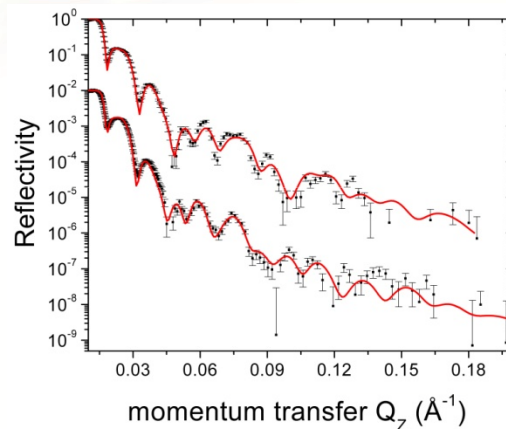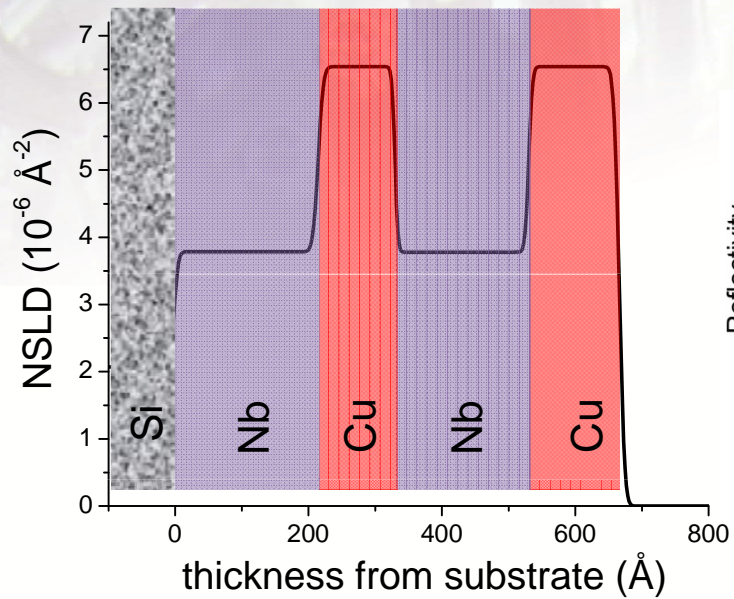
He enriched regions at Cu/Nb interfaces

- He trapped at Cu/Nb interface
- Cu is preferred

Results on Sample [Cu/Nb]$_2$

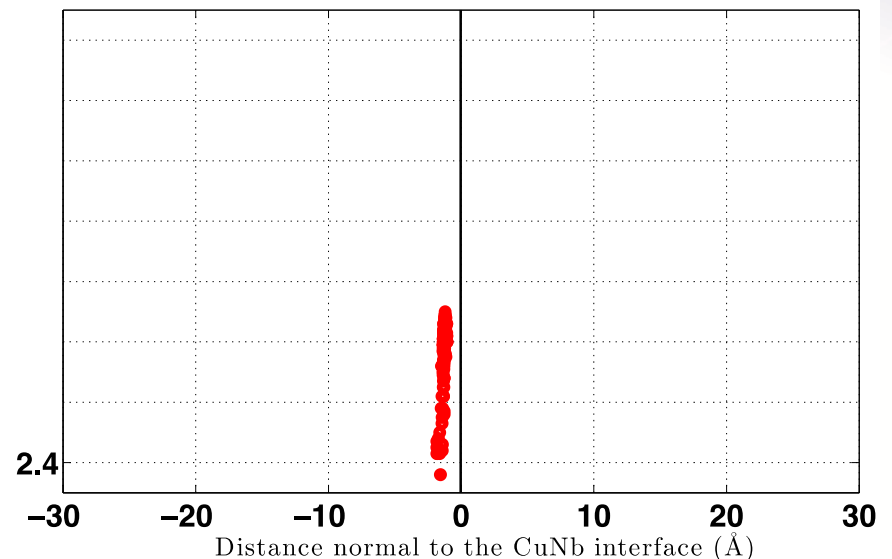|	Layer	Thickness (Å)	SLD (10^{-6} Å^{-2})	Roughness (Å)	He (at. %)
As-prepared	Cu	136	6.54	9	
	Nb	201	3.78	6.4	
	Cu	115	6.54	5.3	
	Nb	216	3.78	8.8	
After Implantation	Cu	86	6.53	19.7	
	Cu + He	60	7.0	13	16
	Nb + He	45	4.2	10	20
	Nb	144	3.78	6	
	Nb + He	26	4.2	8.4	20
	Cu + He	40	6.86	19.8	12
	Cu	54	6.5	6	
	Cu + He	24	6.86	18.7	12
	Nb + He	60	3.95	6.4	10
	Nb	180	3.79	19.3	

Similar behavior as [Cu/Nb] sample; Interfacial region swells ~ 10 times

Atomistic modeling

- Based on Cu-Nb-He EAM Potential
- The formation energy of He defects is **lower** at the Cu-Nb interface compared to fcc Cu and bcc Nb
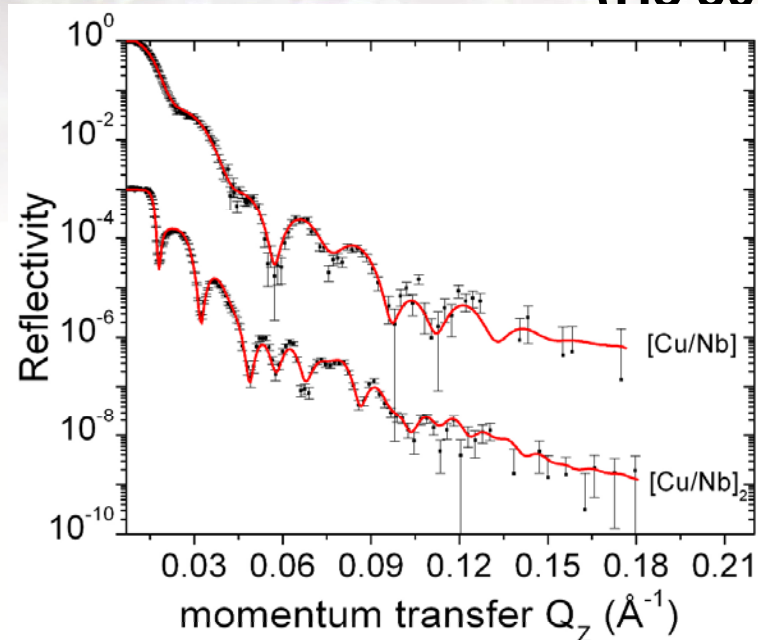- Cu/Nb interface is preferred
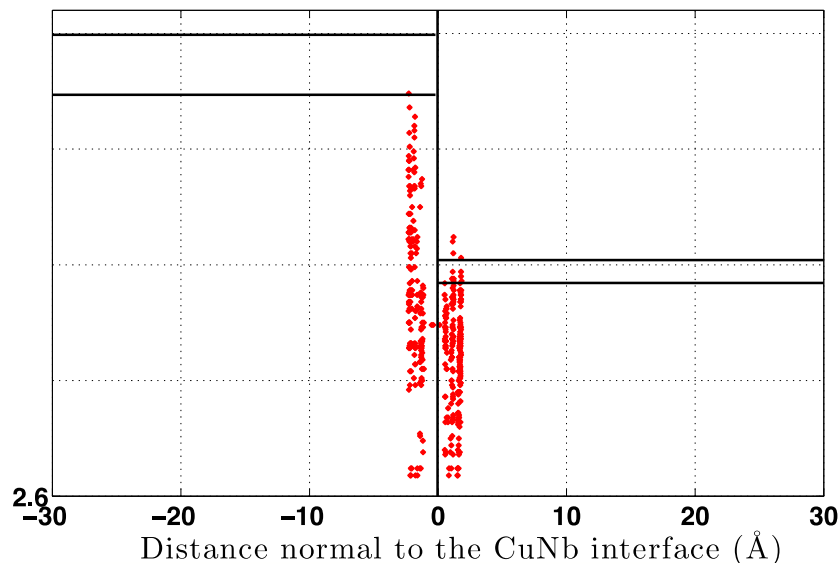
Variation of the He interstitial energy in the direction normal to the Cu-Nb interface

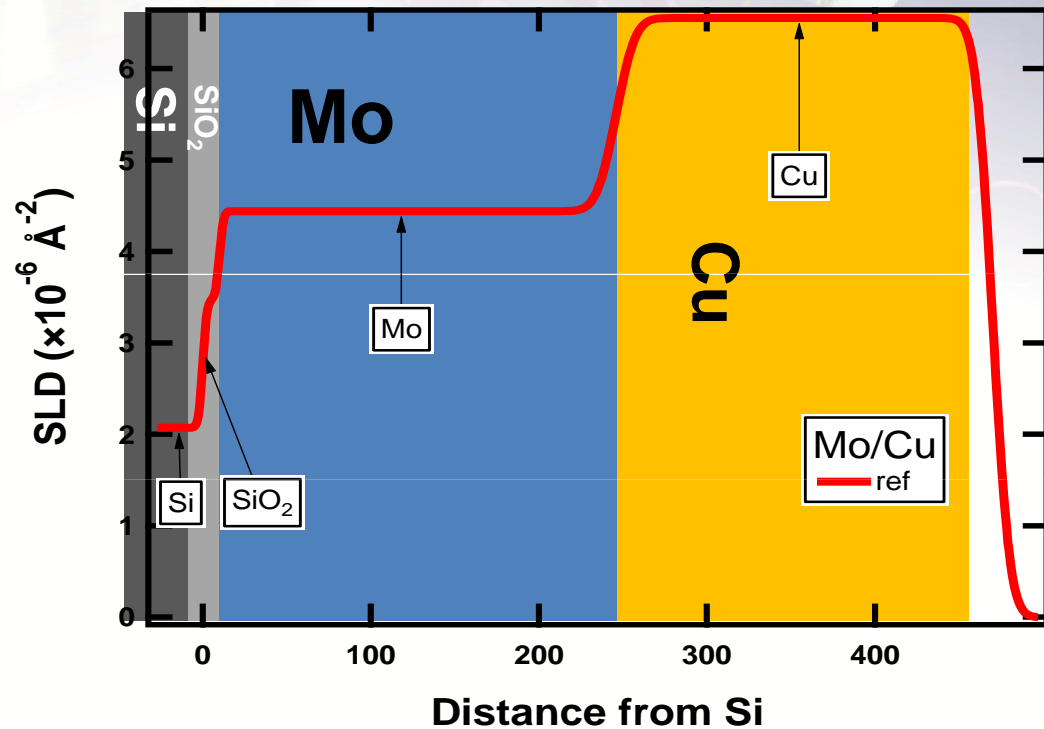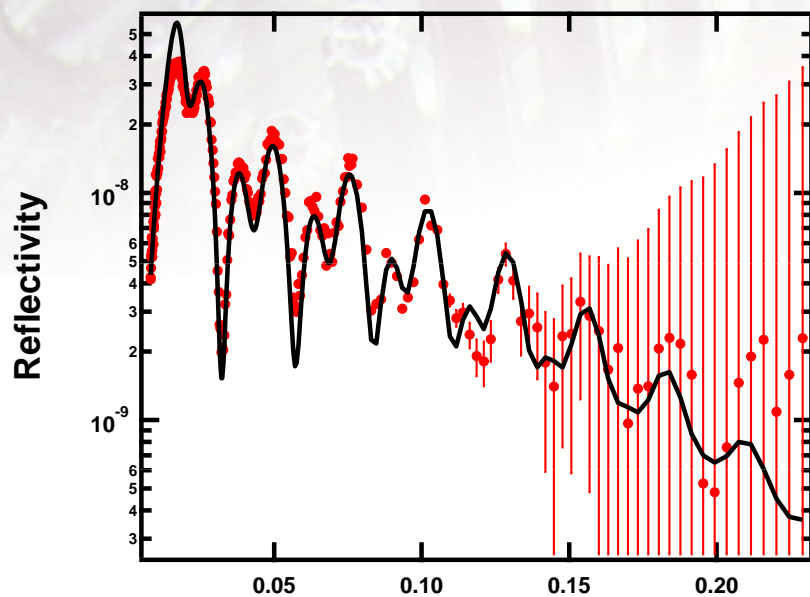Variation of the He substitutional energy in the direction normal to the Cu-Nb interface

Cu/Nb bi-layers sputtered in He atmosphere (He 50% balanced with Ar)

	Layer	Thickness (Å)	SLD (10^{-6} Å^{-2})	Roughness (Å)	He (at. %)
[Cu/Nb]	Cu	122	6.45	16.5	
	Nb	213	3.48	16	
[Cu/Nb]$_2$	Cu	125	6.49	9	
	Nb	210	3.51	15	
	Cu	115	6.47	14	
	Nb	220	3.49	16	

- Homogeneous He distribution
- SLD_{Nb}: Reduced by 8%
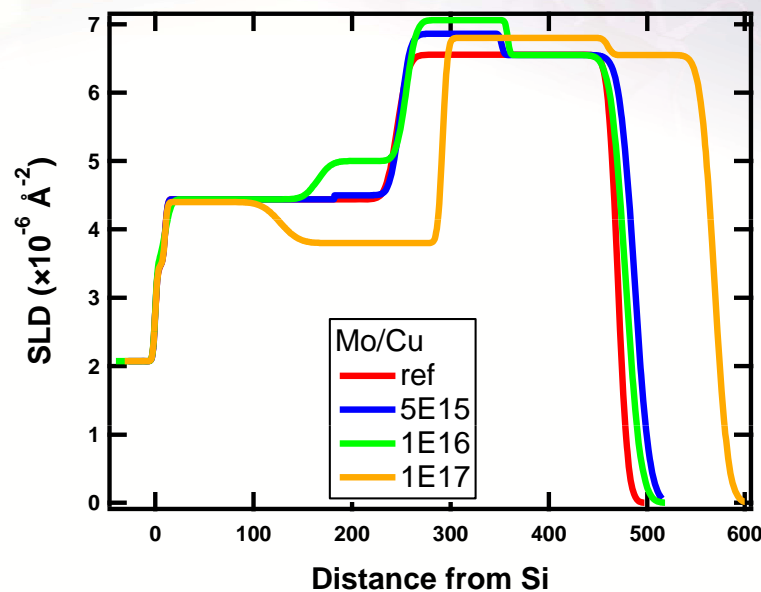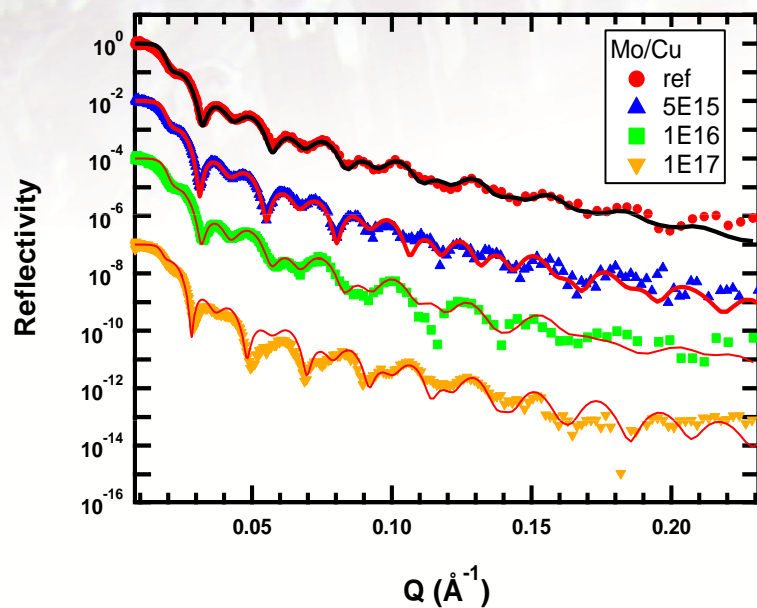- SLD_{Cu}: Reduced by 1%

Cu/Mo Sample

Implanted with difference dose

Cu/Mo Sample

Dependence on Implantation Fluence

- Implantation Fluence has effect on the He trapping behavior
- Critical concentration can be determined

Conclusion

- He is trapped at Cu/Nb , Cu/Mo interfaces.

- He is trapped interstitially

- The interface swells ~ 10 times

- The layered structure retains despite the swell of interfaces.

Future work

- Cu/V system

- Annealing of the Implanted metal bi-layers

- ^{3}He vs. ^{4}He: Bigger cross section

Thanks